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THE ROLE OF SLEEP QUALITY IN GLYCEMIC CONTROL AMONG DIABETIC PATIENTS IN SAUDI ARABIA: A CROSS-SECTIONAL STUDY

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Abstract

Background: Diabetes mellitus (DM) is an important public health problem in Saudi Arabia, and sleep quality may adversely affect glycemic control. Therefore, it is important to understand this relationship in total diabetes therapy.

Objective: To study the relationship between sleep quality and glycemic control in Saudi patients with diabetes.

Methods: This cross-sectional study was conducted from May to May 2025 at the Aseer Central Hospital, Abha, Saudi Arabia. Convenience sampling was used to recruit adult patients with diabetes (aged ≥18 years). Sleep quality was evaluated using the validated Pittsburgh Sleep Quality Index (PSQI), with a score of >5 defined as poor quality of sleep. Glycemic control was defined as an uncontrolled HbA1c level, with HbA1c ≥7%. The chi-square test, Pearson and Spearman correlations, independent t-tests, and logistic regression were used for statistical analysis.

Results: Thirty-eight diabetic patients with complete data were included (mean age: 50.0 ± 12.3 years; 52.6% male; 92.1% Type 2 DM). The incidence of poor sleep quality was 65.8% (mean PSQI 7.97 ± 4.43), and 50.0% had uncontrolled glycemia (mean HbA1c 7.29 ± 0.94%). There was a statistically significant positive correlation between PSQI and HbA1c ($r = 0.425$, $p = 0.008$). Poor sleepers had significantly higher HbA1c levels than did good sleepers (7.52% vs. 6.85%, $p = 0.036$). Patients with uncontrolled glycemia had higher PSQI scores than those with controlled glycemia (10.58 vs. 5.37, $p < 0.001$). For each 1-point increase in the PSQI score, there was a 43.6% increase in the odds of uncontrolled glycemia.

Conclusion: Poor sleep quality was significantly associated with poor glycemic control among patients with diabetes in Saudi Arabia. These results underscore the need to treat sleep disorders as a potential element in overall diabetes management plans.

Keywords: Sleep quality, PSQI, diabetes mellitus, glycemic control, HbA1c, Saudi Arabia

Introduction

Diabetes mellitus (DM) is a significant global public health issue that decreases life expectancy and increases morbidity due to both microvascular and macrovascular complications, such as ischemic heart disease, stroke, peripheral vascular disease, and a reduction in quality of life. In 2021, the International Diabetes Federation announced that 10.5% of the global population was living with DM, indicating the scale of the epidemic. The prevalence of DM in Saudi Arabia is especially alarming as it is considered the second highest in the Middle East and the seventh highest worldwide; almost 7 million people are affected, and a further 3 million are at high risk for the disease. The prevalence of DM in Saudi Arabia has increased 10-folds during the last 30 years, ranging from 23.7 to 61.8% in different provinces of the country.

Sleep is a fundamental physiological process that brings with it a host of alterations, such as reduction in peripheral vascular resistance and cardiac output, leading to decreased blood pressure, secondary autonomic nervous system depression, breathing pattern modulated by substances secreted during sleep, and hormone secretion patterns modified during sleep. Sleep deprivation results in leptin hypersecretion, which promotes food consumption, mainly carbohydrates, and can

worsen obesity, a major risk factor for diabetes mellitus and other chronic degenerative diseases. The association between sleep and metabolic health is bidirectional and complex. Sleep Disorders Are Common in People with Diabetes: Sleep disorders are common in people with diabetes, with prevalence rates from 42 to 71% in patients with type 2 diabetes mellitus (T2DM). In addition, 72.5% of Saudi adults have poor sleep quality, and one in three middle-aged Saudi males is at a risk of obstructive sleep apnea.

The physiological processes that mediate the effects of sleep disorders on glycemic control are complex. Sleep deprivation has been found to increase blood sugar levels by altering glucose metabolism and increasing cortisol levels, leading to impaired management of diabetes and a higher risk of developing the disease. With chronic systemic diseases such as diabetes, patients need good quality sleep more so, with evidence suggesting that these patients are more likely to be affected with co-existent sleep disorders in up to one-third as compared to less than ten percent found in control subjects. In addition, it has been reported that patients with diabetes have an increased prevalence of OSA, excessive daytime sleepiness and poor health outcomes.

Although there has been increasing evidence on the importance of sleep quality in metabolic health, findings regarding the significant relationship between glycemic control and sleep disorders in the literature are inconsistent. However, non-drug sleep treatment is affordable and applicable in the setting of limited resources, and might be a useful tool for addressing these problems. Since both diabetes and sleep disorders are common in this region, it is particularly essential to know the extent to which sleep quality affects glycemic control among the Saudi population.

PSQI is a reliable and valid measure of sleep quality. There is substantial evidence that the PSQI is reliable and valid in a variety of populations along with other clinical measures. The scale has good test-retest reliability (r = 0.87-0.994) and good internal consistency (Cronbach's Î± = 0.824-0.845). It has been validated in patients with diabetes, insomnia, and other chronic diseases, with a sensitivity of 98.7% and specificity of 84.4% for identifying sleep disturbances using a cutoff score of 5.

Due to the high prevalence of diabetes, poorly controlled sleep in Saudi Arabia, and contradictory findings in the literature, this study was designed to assess the burden of sleep quality on glycemic control among diabetic patients in Saudi Arabia. The objectives of this study were to (1) estimate the prevalence of poor sleep quality in patients with diabetes mellitus, (2) investigate the relationship between sleep quality and glycemic control, and (3) evaluate the difference in glycemic control indices between good and bad sleepers. We believe that sleep disturbances may accelerate the risk of diabetes-related complications, and thus, poor sleep quality is positively associated with poor glycemic control among patients with diabetes mellitus in Saudi Arabia.

Methods

Study Design and Setting

This analytical cross-sectional study is a quantitative type of research conducted at the Outpatient Clinic of Aseer Central Hospital in Abha, Saudi Arabia, in May 2025. This study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies. The cross–sectional design was deemed suitable for assessing the relationship between sleep quality and glycemic control at one point in time.

Sample Size Calculation

The required sample size was calculated by approximating the size of the target population with Epi Info 7 software, and the confidence level was set at 95% with a margin of error of 5%, for a rate of poor sleep quality among Saudi diabetic patients of 50%. According to this calculation, the lowest

required number of samples was 385. Convenience sampling was used to recruit participants from an outpatient diabetic clinic.

Participants and Eligibility Criteria

The inclusion criteria were as follows: patients with type 1 or 2 diabetes (age > 18 years) who attended the diabetic center at Aseer Central Hospital. The participants had to be Arabic speakers and were willing to participate. Exclusion criteria were as follows: (1) pregnancy; (2) iron deficiency anemia, hemoglobinopathy, chronic kidney disease, or previous blood transfusion; (3) history of drug or analgesic addiction; (4) aphasic, mentally retarded, and/or unable to cooperate during assessment; (5) not speaking Arabic; (6) illiterate; and (7) incomplete medical records or no measurement of HbA1c in the previous 3 months.

Data Collection

Data were gathered via a self-administered semi-structured questionnaire delivered to the [language] participants. The questionnaire had two principal parts. Section I gathered information on sociodemographic and clinical factors such as age, biological sex, marital status, educational level, job type, smoking habits, exercise regime, coffee consumption, medical history, diabetes complications, insulin use, hypoglycemia history, type of diabetes, duration of diabetes, and HbA1c level.

Part II: For the time spent and style of sleep, the reliable and validated Pittsburgh Sleep Quality Index (PSQI) was applied. The PSQI includes 19 self-rated questions and generates the following seven component scores that assess different dimensions of sleep quality over the last month:1) subjective sleep quality, 2) sleep latency, 3) sleep duration, 4) habitual sleep efficiency, 5) sleep disturbances, 6) use of sleeping medication, and (7) daytime dysfunction. Components are scored from 0 to 3, where 0 indicates no difficulty and 3 indicates the most difficult. The component scores were added to generate a global PSQI score ranging from 0 to 21, with higher scores representing worse sleep quality. To classify poor sleepers (PSQI >5) and good sleepers (PSQI ≤5), a cutoff score of 5 was adopted, exhibiting a sensitivity of 89.

Recent HbA1c results were collected from the medical records. Glycemic control was defined as good (HbA1c<7%) or poor (HbA1c≥7%), according to the clinical guidelines for T2DM, based on HbA1c levels.

Variables

The main outcome variable was glycemic control status (well vs. poor) defined based on HbAlc using a 7% cutoff. The main exposure variable was sleep quality, as assessed using the PSQI global score, with good sleep (PSQI ≤5) or poor sleep (PSQI >5) included as categories. Other information gathered included sociodemographic characteristics (age, sex, marital status, educational attainment, and occupation), lifestyle characteristics (smoking status, tea consumption, and physical activity), and clinical features (type of diabetes, diabetes duration, comorbidity, and insulin usage).

Statistical Analysis

Statistical analyses were performed using Python version 3.7.9, using relevant statistical packages. Data cleaning procedures were employed to detect and remove outliers and maintain data quality. Descriptive statistics were computed for each variable. For continuous variables, values are reported as mean ± standard deviation (SD) for categorical variables as counts and percentages.

The chi-square test was used to analyze the relationship between sleep quality status (good vs. poor) and glycemic control status (good vs. poor) at a significance level of 0.05. Pearson's correlation coefficient was used to evaluate the linear relationship between the PSQI global scores and HbA1c levels among continuous variables. The Spearman's rank correlation coefficient was also

determined as a non-parametric correlation. (1) to compare mean HbA1c values in good and poor sleepers and (2) to compare mean PSQI scores in patients with controlled and uncontrolled glycemia. Univariate logistic regression was conducted to estimate the odds ratio (OR) of poor glycemic control for a one unit increase in the ISI score.

All statistical tests were two-sided, and statistical significance was set at $p < 0.05$. The results are displayed in tables and figure, using the recommended scientific reporting style.

Ethical Considerations

The study protocol followed the principles of the Declaration of Helsinki and was approved by the appropriate ethics committee. This study was approved by the Ethics Committee of the Saudi Ministry of Health. The study was voluntary and anonymous, so that individuals could withdraw at any time without consequences. Prior to participation in the study, written informed consent was obtained from all subjects after the aims, methods, and potential benefits of the study were fully explained. "This made sure that the participants were well informed and freely consented to participate without any coercion, and it was also assured that their privacy and confidentiality were sustained during the whole process of the study.

Results

Participant Characteristics

In total, 385 respondents answered the survey. Among them, 174 agreed to participate. After cleaning the data and excluding cases with missing values, 38 individuals with complete data on both PSQI scores and HbA1c levels were included in the final analysis. The demographic and clinical characteristics of the study participants are presented in **Table 1**.

Table 1: Baseline Sociodemographic and Clinical Characteristics (N=38)

Characteristic	**n (%)/Mean±SD**
Age (years)	50.0 ± 12.3
Gender	
Male	20 (52.6%)
Female	18 (47.4%)
Marital Status	
Married	29 (76.3%)
Single	5 (13.2%)
Divorced	4 (10.5%)
Education Level	
University	25 (65.8%)
Secondary	9 (23.7%)
Postgraduate	4 (10.5%)
Smoking Status	

Non-smoker	36 (94.7%)
Smoker	2 (5.3%)
Coffee Consumption	
No	29 (76.3%)
Yes	9 (23.7%)
Physical Exercise	
No	28 (73.7%)
Yes	10 (26.3%)
Diabetes Type	
Type 2	35 (92.1%)
Type 1	3 (7.9%)
Presence of Comorbidities	
No	25 (65.8%)
Yes	13 (34.2%)

The average age of the respondents was 50.0 ± 12.3 years, for the original diabetic cohort, with ages ranging from 18 to 100 years. The participants were 20 males (52.6%) and 18 females (47.4%). Most of the participants were married (76.3%), had education up to the university level (65.8%), were non-smokers (94.7%), did not drink coffee (76.3%), and did not exercise regularly (73.7%). In terms of diabetes type, the majority had type 2 diabetes (92.1%), with only 3 individuals (7.9%) living with type 1 diabetes. One-third of the participants (34.2%) reported the presence of comorbidities besides diabetes.

Sleep Quality Assessment

Table 2 presents the individual components of sleep quality and the total PSQI scores. The average global PSQI score was 7.97 ± 4.43, with a minimum value of 1 and a maximum of 16. Of all the seven components of PSQI, sleep latency had the highest mean score (1.89 ± 0.69), with subjective sleep quality (1.53 ± 0.95) as the second highest, followed by habitual sleep efficiency (0.97 ± 1.24), sleep duration (1.05 ± 0.93), daytime dysfunction (1.00 ± 0.77), sleep disturbances (0.92 ± 0.43), and use of sleep medication (0.61 ± 1.05).

Table 2: Sleep Quality Components and PSQI Scores (N=38)

PSQI Component	Mean ± SD	Range
Component 1: Subjective Sleep Quality	1.53 ± 0.95	0 - 3
Component 2: Sleep Latency	1.89 ± 0.69	1 - 3
Component 3: Sleep Duration	1.05 ± 0.93	0 - 3

Component 4: Habitual Sleep Efficiency	0.97 ± 1.24	0 - 3
Component 5: Sleep Disturbances	0.92 ± 0.43	0 - 2
Component 6: Use of Sleeping Medication	0.61 ± 1.05	0 - 3
Component 7: Daytime Dysfunction	1.00 ± 0.77	0 - 3
PSQI Global Score	7.97 ± 4.43	1 - 16
Sleep Quality Category	**n (%)**	
Good Sleep (PSQI ≤ 5)	13 (34.2%)	
Poor Sleep (PSQI > 5)	25 (65.8%)	

Based on the previously defined cut-off of PSQI >5, 25 participants (65.8%) were poor sleepers and 13 (34.2%) were good sleepers. This suggests that poor sleep quality is common in patients with diabetes.

Glycemic Control Status

Table 3 Describes the data on glycemic control and the statistical relationships. The average HbA1c in the sample was 7.29 ± 0.94%, with a minimum of 6.2% and a maximum of 9.5%. When the cut-off for controlled glycemia was taken as HbA1c <7%, the proportion of patients who had controlled glycemia was exactly half (19 patients, 50.0%), while the other half (19 patients, 50.0%) had uncontrolled glycemia.

Table 3: Glycemic Control and Association with Sleep Quality (N=38)

Variable	**n (%)/Mean ± SD**	**Details**
HbA1c (%)	7.29 ± 0.94	Range: 6.2 - 9.5%
Glycemic Control Category		
Controlled (HbA1c < 7%)	19 (50.0%)	
Uncontrolled (HbA1c ≥ 7%)	19 (50.0%)	
Association Analysis		
Chi-square test (Sleep Quality vs Glycemic Control)		
χ^2 statistic	7.483	
p-value	0.006	**Significant**
Correlation Analysis (PSQI vs HbA1c)		

Pearson r	0.425	p = 0.008
Spearman ρ	0.512	p = 0.001

We tested the association between sleep quality and glycemic control groups using the chi-square test. The association between sleep quality and glycemic control (poor vs. good) was statistically significant (χ^2 = 7.483, df =1, p = 0.006). Of the good sleepers (PSQI ≤5), 84.6% had controlled glycemia, while 15.4% had uncontrolled glycemia. However, among bad sleepers (PSQI >5), only 32.0% had controlled glycemia and 68.0% had uncontrolled glycemia.

Correlation Analysis

Correlation analyses showed significant positive correlations between the PSQI scores and HbA1c values. The Pearson correlation coefficient was r=0.425 (p=0.008), indicating a moderately positive correlation. Spearman's correlation coefficient was ρ=0.512 (p=0.001), implying a marginally stronger monotone relationship in the presence of nonlinearity. Both correlation coefficients were significant at p < 0.01, which supports the hypothesis that poor sleep quality predicts poor glycemic control.

Figure 1: Scatter Plot of PSQI vs HbA1c with Correlation Analysis

Point plot showing a positive correlation between the PSQI Global Score and HbA1c in patients with diabetes (r = 0.425, p = 0.008). Reference lines represent cutoff values for poor sleep quality (PSQI > 5) and uncontrolled glycemia (HbA1c ≥ 7%).

This scatter plot represents the positive correlation between the PSQI Global Score and the levels of HbA1c in the study subjects. The regression line shows the trend with horizontal and vertical reference lines at the clinical cutoffs (PSQI = 5 for poor sleep and HbA1c = 7% for uncontrolled

glycemia). The strong correlation (r = 0.425, p = 0.008) suggests that patients with higher PSQI scores denoting poor sleep quality had higher HbA1c levels, indicating poor glycemic control.

Group Comparisons

Table 4 DemographicThe results of the independent samples t-test for HbA1c between sleep quality group as well as PSQI score between glycemic control group are shown in Table 1 Patients with poor sleep quality had significantly higher mean HbA1c than those with good sleep quality (7.52 ± 0.84% vs. 6.85 ± 1.00%, t = -2.181, p = 0.036). Such a 0.67-percentage-point difference in HbA1c is clinically significant, because reductions of this magnitude have been related to decreased risk of diabetic complications.

In contrast, individuals with uncontrolled glycemia scored significantly higher on the PSQI than those with controlled glycemia (10.58 ± 3.93 vs. 5.37 ± 3.24, t = 4.459, p < 0.001). The 5.21-point difference on the PSQI scale was substantial, revealing that the sleep quality of those who had not controlled their diabetes was far worse. A p-value of < 0.001 showed a highly significant difference between these groups.

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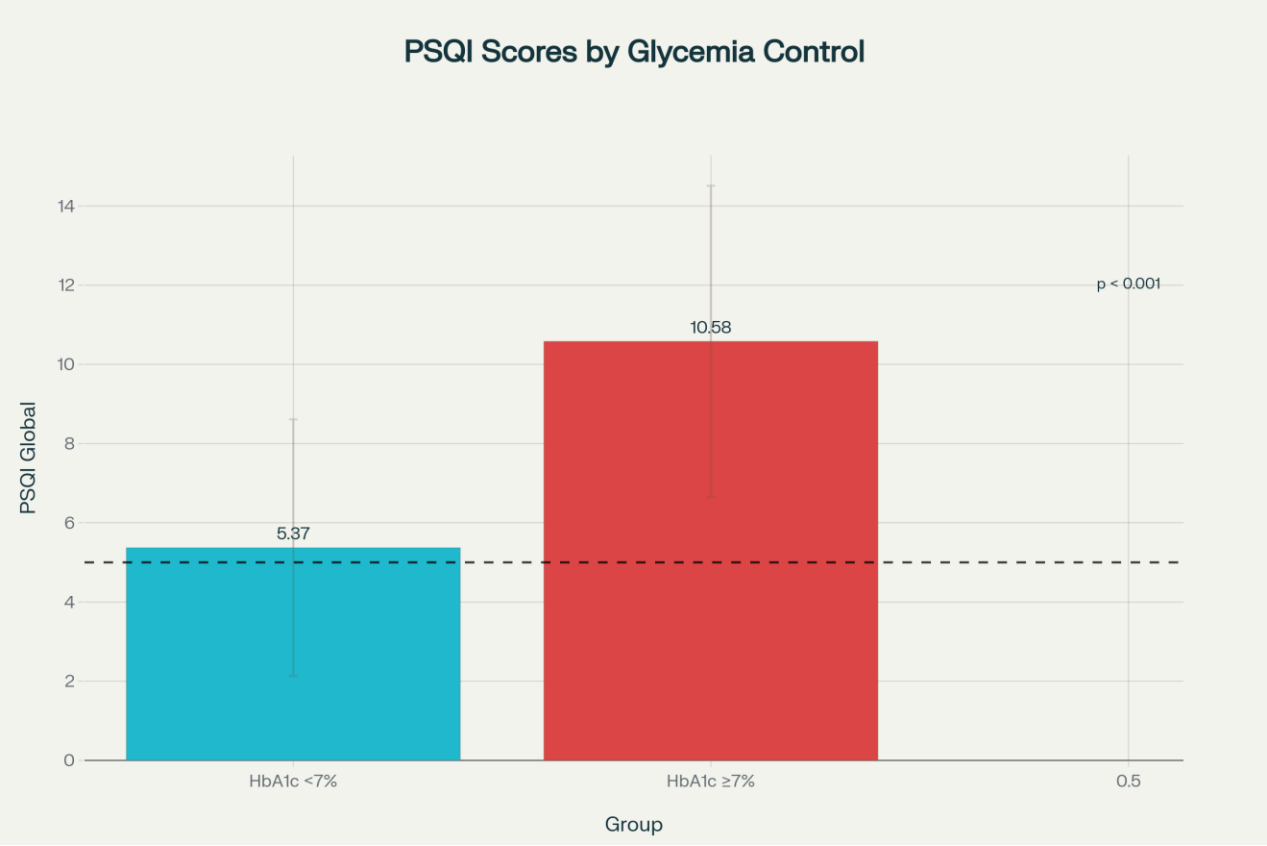
Table 4: Comparison of HbA1c and PSQI Scores by Sleep Quality and Glycemic Control Groups (N=38)

Comparison	Group	n	Mean ± SD	Test Statistic	p-value
HbA1c (%) by Sleep Quality					
	Good Sleep (PSQI ≤ 5)	13	6.85 ± 1.00	t = -2.181	**0.036**
	Poor Sleep (PSQI > 5)	25	7.52 ± 0.84		
PSQI Score by Glycemic Control					
	Controlled (HbA1c < 7%)	19	5.37 ± 3.24	t = -4.459	**<0.001**
	Uncontrolled (HbA1c ≥ 7%)	19	10.58 ± 3.93		

Figure 2: Bar Chart Comparing PSQI Scores by Glycemic Control Status



PSQI global score in patients with controlled versus uncontrolled glycemia. Individuals with uncontrolled glycemia had a significantly higher PSQI score (worse sleep quality) than those with controlled glycemia ($p<0.001$).

Between-subjects comparison of the mean global PSQI score in T2DM patients with controlled (fN = 32) and uncontrolled (fN = 36) glycemia. Error bars correspond to ± 1 standard deviation. Individuals with uncontrolled glycemia (HbA1c ≥ 7%) exhibited a significantly higher PSQI score (worse sleep quality) than those with controlled glycemia (HbA1c < 7%). The horizontal guideline at PSQI = 5 represents the cut-off value for poor sleep quality. The significant difference ($p < 0.001$) indicates a strong link between poor sleep quality and uncontrolled diabetes.

Logistic Regression Analysis

To estimate the odds of uncontrolled glycemia, a logistic regression was conducted to examine the relationship between the PSQI scores and the odds of having poorly controlled blood sugar. The findings indicated that for a 1-point increase in the PSQI global score, the odds of having uncontrolled glycemia (HbA1c ≥7%) was 1.436 (regression coefficient $\beta = 0.362$), corresponding to a **43.6% increase in the odds of having uncontrolled glycemia**. This dose-dependent association further underlined the association between sleep quality and glycemic control.

Discussion

Key Findings

This was a non-experimental, descriptive, cross-sectional study conducted to examine sleep quality and glycemic control in diabetic patients in Saudi Arabia. The results showed three major findings: (1) a high proportion of poor sleep quality (65.8%) among patients with diabetes, (2) a significant positive association between PSQI scores and HbA1c values ($r = 0.425$, $p = 0.008$), and (3) significantly worse glycemic control in poor sleepers than in good sleepers (HbA1c 7.52% vs. 6.85%, $p = 0.036$). These results confirm the hypothesis that poor sleep quality is strongly related to poor glycemic control in patients with diabetes.

Interpretation of Findings

The high proportion (65.8%) of poor sleep quality identified in this study is in line with earlier reports that indicated that 42-71% of individuals with type 2 diabetes mellitus suffered from sleep disturbance. This prevalence is also in line with the report of poor sleep quality in 72.5% of Saudi adults. Our findings, along with the fact that sleep disorders are a common problem in patients with diabetes in Saudi Arabia, as documented in the literature.

A significant, moderately strong correlation was found between PSQI and HbA1c scores ($r = 0.425$, $p = 0.008$), indicating that poorer sleep quality was related to worse glycemic control. This relationship was also confirmed by the Spearman's rank correlation coefficient ($\rho = 0.512$, $p = 0.001$), which considers possible nonlinear relationships. "The $\chi 2$ test was significant ($\chi^2 = 7.483$, $p = 0.006$), indicating that poor sleepers were more than three times as likely to have uncontrolled glycemia than good sleepers (68.0% versus 15.4% with uncontrolled glycemia).

Poor sleepers also had significantly higher HbA1c values (7.52% vs. 6.85%, $p = 0.036$), which was clinically relevant. A difference of 0. A 0.67 percentage point decrease in HbA1c is clinically relevant since even small decrements in HbA1c have been linked to a reduced risk of diabetic sequelae. In contrast, sleep quality was dramatically poorer in patients with uncontrolled glycemia (PSQI 10.58 vs. 5.37, p 0.001), with mean PSQI scores more than double the cutoff value for poor sleep quality.

Logistic regression showed that the odds of uncontrolled glycemia increased by 43.6% for every 1-point increase in the PSQI score, giving a numeric expression of this association. This dose-response relationship provides stronger evidence for the link between sleep quality and glycemic control, although the cross-sectional nature of the data limits inferences about causality.

Physiological Mechanisms

Several physiological processes may underlie the link between sleep quality and glycemic control. Sleep deprivation has been established to raise blood glucose concentration through mechanisms that impair glucose metabolism and stress the body through elevated cortisol levels, thereby not only contributing to poor diabetes management but also increasing the risk of development of the disease. While sleeping, an individual goes through a series of physiological processes, such as a decrease in peripheral vascular resistance and cardiac output, which contribute to rest in blood pressure because of reduced sympathetic tone. Sleep disturbances can interfere with physiological processes and cause metabolic disorders.

Leptin hypersecretion, which results from sleep deprivation, promotes food consumption, especially that of carbohydrates, and may aggravate obesity as a major risk factor for diabetes mellitus. Furthermore, sleep disorders, including obstructive sleep apnea (OSA), are frequent among patients with diabetes and may contribute to worsening glycemic control by inducing intermittent

hypoxia and sleep fragmentation. The two-way relationship between diabetes and sleep is important for speculation on because diabetes itself may lead to sleep problems.

Comparison with Previous Studies

The « Humanized task "You should know that the conflicting results found in the literature evaluating the relationship between glycemic control and sleep alterations add further importance to the demonstration of this relationship in our study." are: Glycemic control in patients with diabetes is associated with sleep disturbances Our results agree with those of studies that found important relations between sleep quality and glycemic control, emphasizing the need to consider sleep disorders in the management of diabetes"." Our results are in agreement with those of other studies that found significant correlations between sleep quality and glycemic control," stressing the importance of considering sleep disorders in diabetes treatment.

Several studies have demonstrated the validity of the PSQI in different populations and clinical settings with high test-retest reliability (r = 0.87-0.994) and good internal consistency (Cronbach s Î α = 0.824-0.845). The tool was shown to be 98.7% sensitive and 84.4% specific for identifying sleep disorders, applying a cut-off score of 5. The application of the PSQI in individuals with diabetes has shown validity in earlier studies, giving us confidence in the utilization of this tool in this study.

Clinical Implications

Our results have several clinical implications. Poor sleep quality is common in patients with diabetes (65.8%), and sleep disturbance screening should be part of regular diabetes care. The strong correlation between sleep quality and glycemic control also suggests that treating sleep disorders may be greatly underappreciated in diabetes management. Compared with good sleep quality, poor sleep quality is significantly correlated with poorer glycemic control, and controlling for several confounders, including diabetes duration and type of diabetes, poor sleep quality is significantly associated with poor glycemic control, especially in subjects with type 1 diabetes, a detrimental association finally confirmed by the meta-analysis.

Non-pharmacological intervention for sleep, which would be the most cost-effective and also the most appropriate for a setting with limited resources, might be a good way to address these problems. The interventions included the following:

• Sleep hygiene education.
• Cognitive behavioral therapy for insomnia
• Screening and treatment of sleep apnea
• Lifestyle changes for better sleep.

Poor sleep quality was related to 43.6% higher odds of uncontrolled glycemia per 1-point increase in PSQI score, indicating that better sleep quality can exert clinically meaningful benefits on glycemic control. Objects of the Study

In clinical practice, it is important to remember the inverse association between sleep and diabetes. Although poor sleep may lead to poor glycemic control, poorly controlled diabetes may also result in disrupted sleep due to factors such as nocturia, neuropathic pain, and nocturnal hypoglycemia; thus, interventions targeting both sleep quality and diabetes management are necessary.

Strengths and Limitations

Strengths:

- Utilized a validated, well-known tool for sleep quality assessment (PSQI) with known reliability and validity in patients with diabetes
- This cross-sectional study adhered to the STROBE statements to improve the transparency and completeness of reporting.

- Objective assessment of glycemic control was obtained by the measurement of HbA1c from medical records
- A variety of statistical methods (chi-square, correlation, t-tests, and logistic regression) were used to thoroughly investigate the association.

Limitations:

1. Cross-sectional study: unable to establish temporal or causal relationships. Long-term studies are necessary to confirm whether poor sleep leads to worsening glycemic control or vice versa.
2. Small sample size: The completed sample of 38 participants was much smaller than the intended sample size of 385, reducing statistical power and generalizability. This raises the possibility of a Type II error.
3. Selection bias: Convenience sampling could affect generalizability.
4. Self-reported data: The study used self-reported measures of sleep quality, not objective measures such as polysomnography or actigraphy.
5. Undetermined sleep disorder: A common sleep disorder, such as obstructive sleep apnea (OSA), which shares a high comorbidity rate with diabetes, was not investigated in this study.
6. Absent clinical parameters: Data on diabetes duration, medication this provider please enter your full name below, and diabetic complications were not obtained.
7. Single-center study: This study was conducted at a single center in Saudi Arabia, and the results may not be generalizable to other centers or populations. Potential residual confounding: The study was adjusted for potential confounders, but residual confounding by unmeasured factors (depression, anxiety, and other comorbidities) cannot be ruled out.

Future Research Directions

The limitations could be addressed by future research in a number of ways.

• Longitudinal/prospective cohort studies to determine temporal and potential causal pathways between sleep quality and glycemic control

• Intervention trials to evaluate whether improvements in sleep quality result in improved glycemic control.

Objective sleep measures (polysomnography and actigraphy) in conjunction with subjective measures.

• Specific sleep disorder evaluation, particularly obstructive sleep apnea

• Larger sample sizes permit multivariate analyses with adjustment for multiple confounders

• Qualitative studies of patient and provider experience

Cost-effectiveness analyses evaluating sleep interventions within diabetes care **Generalizability**

It is important to note the limitations of this study, as it was a single center in Saudi Arabia and the sample mainly consisted of married, educated, non-smokers with type 2 diabetes; thus, the results may not be applicable to other centers. These results may not be generalizable to other populations, healthcare, or cultural contexts. Confirmation of these findings in larger, more heterogeneous samples from multiple centers would strengthen the generalizability of the results.

Conclusion

This study found a significant relationship between poor sleep quality and glycemic control in patients with diabetes in Saudi Arabia. The incidence of poor sleep quality was high (65.8%), and poor sleepers exhibited significantly elevated HbA1c levels compared with good sleepers. The significant positive relationship between PSQI scores and HbA1c levels, and the associated finding that a 1-point increase in PSQI score was linked with a 43.6% higher likelihood of uncontrolled

glycemia, emphasizes that addressing sleep disturbance in diabetes management could have significant clinical implications.

These results indicate that screening for sleep problems on a routine basis should be considered as part of holistic diabetes management and that treatment strategies targeting the enhancement of sleep quality could be a novel, cost-effective approach for better glycemic control. Nevertheless, the cross-sectional design and small sample size preclude any causal conclusions, and further longitudinal and interventional studies are warranted to determine cause-effect relationships and to assess the effectiveness of sleep-targeted interventions in enhancing glycemic control.

Considering the high prevalence of diabetes in Saudi Arabia and the alterable nature of sleep disturbances, improving sleep quality is a salient target for improving the outcomes in these patients. Providers of care should know the link between sleep and glycemic control and should consider evaluating and treating sleep quality in the evaluation of patients with diabetes. R&D for frugally priced suitable non-pharmacological sleep interventions adapted for limited resource contexts should be prioritized for future research and clinical pathways.

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Author Contributions
The study conception and design, data collection, statistical analysis, manuscript preparation, and critical revision were performed by the research team.

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Conflicts of Interest
The authors declare no conflicts of interest.

Ethical Approval
This study was approved by the Ethics Committee of the Saudi Ministry of Health. All participants provided written informed consent before participation.

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